

# Wastewater Treatment and its Management of Endocrine Disrupting Chemicals

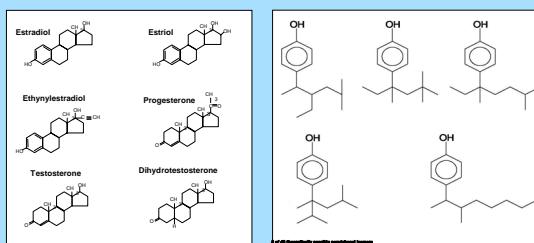
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## Science Questions

**Strategic questions:** How can unreasonable risks be managed? What are the major sources and environmental fates of EDCs?

**Specific questions:** What is the efficacy of wastewater treatment to remove EDCs and improve their management? Are wastewater treatment technologies a significant source of EDC to the environment and can this source be managed?

Research has shown that wastewater treatment (WWT) can be a significant source of endocrine disrupting chemicals (EDCs) to the environment. WWT can include centralized wastewater treatment plants (WWTPs) as well as on-site WWT technologies (e.g., septic systems, constructed wetlands). EDCs that have been found in WWTP effluents (aqueous and biosolids) include estrogenic and androgenic hormones (natural and synthetic), detergent metabolites (alkylphenols), and plasticizers (bisphenol A, phthalates). Though known to be sources of EDCs to the environment, many questions exist as to why some WWTP technologies have higher or lower concentrations in their effluents. Little research has been conducted to demonstrate how unit technology or operational conditions relate to the removal of EDCs. The efficacy of the individual unit processes within the plant is not well characterized. In addition, no significant research has been conducted to evaluate on-site WWT for the management of EDCs. This is important, in that 30% of the US population is served by some form of on-site WWT technology.



## Research Goals

One focus of the EDCs and wastewater research within ORD is to characterize the performance of existing risk management strategies. This research has been started at the bench and pilot scale. Research has been conducted on the fate of alkylphenols and to characterize their biodegradation rates under redox conditions typically found in WWTPs. Research has also been conducted at the pilot scale. Additionally, research is being initiated to evaluate estrogenic and androgenic hormones under similar experimental conditions. At the pilot scale, two fully functioning pilot plants were constructed and operated to simulate a municipal WWTP. The plants were fed a simulated wastewater with constant dosing of selected EDCs to allow a mass balance analysis of the plant and the individual unit processes.

Research has also been initiated at the full plant scale. To date, a project evaluating the efficacy of digesters has been initiated to study alkylphenols, hormones, and bisphenol A. This project is a collaborative effort between ORD, Region 5, and the regional wastewater utility.

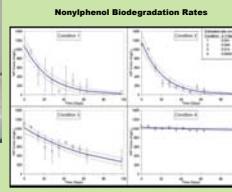
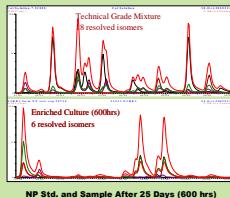
A second focus of this research is to determine techniques to optimize existing management strategies or develop alternative management strategies. Once unit operations and technology performance are understood, engineering solutions can be developed to reduce the discharge of EDCs to the environment. Additional research is being developed in the areas of on-site WWT technologies. These technologies include septic systems, constructed wetlands, and other on-site technologies.

## Bench Scale:

### Biodegradability of EDCs

#### Objective:

- Characterize alkylphenol (AP) biodegradation of under aerobic and anaerobic conditions.
  - Examine kinetics of AP biodegradation.
  - Examine selective isomer biodegradation.
- Characterize the biodegradation of selected estrogenic and androgenic hormones under aerobic and anaerobic conditions
  - Examine kinetics of hormone biodegradation.
  - Examine selective hormone biodegradation or transformations.



## Status of Bench Scale Research

### Alkylphenols

- Aerobic conditions**
  - NP can support aerobic biological growth as a sole carbon source.
  - Biodegradation of NP follows first order kinetics.
  - Selective degradation of NP isomers. Statistically significant difference in the biodegradation rates of the isomers.
  - The less estrogenic isomers are the more recalcitrant isomers.
  - Low yield of AP degraders (Cell yield of 0.25 g-biomass/g-NP)
- Anaerobic conditions**
  - NP is very persistent under the nitrate reducing, sulfate reducing, and methanogenic conditions.
  - Little biodegradation of NP is expected to occur in the anaerobic digesters of WWTPs or in anoxic sediments.

### Estrogenic and androgenic hormones

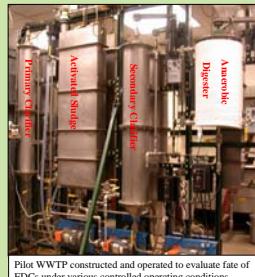
- Analytical methods optimization is underway for small volume samples
- Experiment have been initiated in respirometers and microcosms

## Pilot Scale:

### Date of EDC in Pilot WWTP

#### Objective:

- Develop a functional pilot plant for simulating WWT unit operations
  - The fate of selected EDCs during WWT
  - Determine the efficacy of individual unit operations to manage EDCs
  - Develop a mass balance approach for evaluating the management of EDCs during WWT
  - Evaluating operational changes and their effects on EDC management by WWTPs



Pilot WWTP constructed and operated to evaluate fate of EDCs under various controlled operating conditions.

## Conventional

	Testosterone	Estradiol	Estrene	Ethyneestradiol	NPEOs
Aerobic	100 %	98 %	78 %	30 %	5%
Anaerobic	100 %	97 %	80 %	38 %	4.5%

## Predenitrification

	Testosterone	Estradiol	Estrene	Ethyneestradiol	NPEOs
Aerobic	100 %	100 %	86%	20%	8%
Anaerobic	100 %	97 %	65%	3%	11.8%

## Status of Pilot Scale Research

### Pilot plant

- Developed an operating pilot plant for simulating WWT operations
- Plant runs under two "typical" operating conditions
  - Conventional secondary treatment with waste activated sludge with aerobic and anaerobic sludge digestion
  - Predenitrification conditions of enhanced nitrogen control with waste activated sludge with aerobic and anaerobic sludge digestion

### Performance of pilot plant

- Removal for selected EDCs (shown below) for entire plant
- Mass balance on individual unit processes are in progress

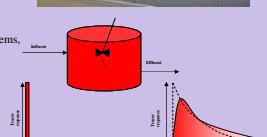
## Field or Operational Scale: WWTPs and their Unit Operations

#### Objective:

- Evaluate the removal of EDCs during selected unit operations
- Compare WWTP designs and the resulting management of EDCs (i.e. compare waste activated sludge to trickling filter plants)
- Evaluate alternative WWT technologies, such as on-site WWT, to manage EDCs (i.e. septic systems, constructed wetlands, package plants)

#### Approach

- Partner with WWTP utilities and operators to conduct unit operations and entire WWTP studies
- Partner with users of on-site WWT technologies to evaluate these systems
- Develop approaches for both unit operations and whole plant mass balances



## Status of Field Scale Research

### Progress

- Partner with WWTP utilities/operators to conduct unit operation and entire WWTP studies
- Partner with users of on-site WWT technologies to evaluate these systems
- Develop approaches for both unit operations and whole plant mass balances
- Evaluate full scale operations of digesters in a waste activated sludge treatment plant for the removal of select EDCs.
- Cooperative project between USEPA ORD, USEPA Region 5, and Greater Chicago Metropolitan Water Reclamation District
- Three digesters have been identified and sampled for evaluating the target levels of EDCs and a conservative tracer
- Evaluate the fate of EDCs during WWT by constructed wetlands treating municipal wastewater
  - Constructed wetland used to manage municipal wastewater for 10-100 people
  - Designed for wastewater and nutrient management not specifically EDCs
  - Evaluate the fate of EDCs during land treatment of biosolids
  - Collaborative project with USEPA ORD, USEPA Reg 5, USDA
  - Biosolids have been land applied and routine monitoring is being conducted to determine the fate of EDCs



### References

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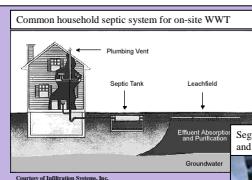
- Bertin, M.A.; Mills, M.A.; Sayles, G.D.; Smirniotis, P. "Aerobic Biodegradation of Nonylphenol in Microcosms: Estimation of Rate by Individual Nonylphenol Isomers". Submitted 2005 to *Water Research*.
- Effective Risk Management of Endocrine Disrupting Chemicals Workshop, Cincinnati, OH, September 18-19, 2001
- "EPA's Risk Management Evaluation of EDCs" Gregory Sayles
  - "Using Bioassays to Evaluate the Performance of Risk Management Techniques" Carolyn Acheson
  - "Biological Fate of Estrogenic Compounds Associated with Sewage Treatment: A Review", Gregory Sayles
  - "An Engineering Approach to Evaluate Estrogenic EDCs Fate During Wastewater Treatment", Paul McCauley

## Impacts and Outcomes

The results of this research can be used now to help WWT operators understand the capability of their plants to remove EDCs, how process variable influence performance, and how to improve the operation of their plants if they wish to minimize effluent levels of EDCs. In the future, if EPA concludes that EDCs levels in effluents must be regulated, the Office of Water will require performance information on conventional and innovative treatment to make regulatory determinations. Using this research, risk managers (EPA, States, municipalities, utilities) can operate the WWT processes to better reduce the loading of EDCs to the environment.

## Future Directions

- On-site wastewater treatment systems and their efficacy in managing EDCs
- Fate of EDCs in sediments near WWT outfalls
- Optimization of WWT systems to manage EDCs
- Continue to collaborate and outreach with our customers in the Regions, States, and WWT professionals
- Expand our research program in WWT to include additional EDCs
- Improve analytical and bioassay methods for risk management research



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